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INTRODUCTION

Technology Assessment has progressed from its earliest beginnings in systems analysis to its present adaptive format as a technology impact assessment methodology. However, the terminology of "Technology Assessment" and, moreover, the structure, scope and purpose of its methodology have undergone continuous change. Over the years it has possessed nearly as many definitions and meanings as there were authors or experimenters in the field.[1] It is alternately considered a technology forecasting tool, an issue identifier, or an environmental impact report. It is often equated with technology transfer, technology utilization or advanced systems planning. It has been used to rationalize a particular program or to undermine one. Perhaps the real meaning and utility of technology assessment is that it contains elements of all the above.

Most proponents of technology assessment would agree that it refers to a systematic planning and forecasting process that identifies options and costs, encompassing economic as well as environmental, political, and social considerations that are both external and internal to the program or project being reviewed, with special focus on technology-related "bad"

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as well as "good" effects.[2] Also, the concept of technology assessment has been broadened to encompass far more than what normally comes to mind when we use the term "technology." As an example, "No-fault Automobile Insurance" may be considered a proper subject for technology assessment on the grounds that it is "social technology" or that its implementation would most certainly have an impact on society.

With this prologue, the present authors offer their definition and suggested utility of technology assessment, adopted after directing several such studies and learning many lessons. A definition that closely identifies these views is, "Technology Assessment is a class of policy studies which systematically examine the effects on society that may occur when a technology is introduced, extended, or modified, with special emphasis on those consequences that are unintended, indirect, or delayed."[3] Technology assessment is first and foremost considered a management aid, the purpose of which should be to assess the impacts of new technologies on society and to identify potential problems, drawbacks, and advantages of individual technologies. The breadth and depth of the analysis of each issue may vary depending on the purpose of the study or state of readiness of the particular technology for application. In other words, the scope of a technology assessment should be a direct function of the nature of the judgments to be made. The considerations must be broader than simply technological and must include the environmental, economic and socio-political issues associated with the introduction of the new technologies. Additionally, technology assessment should identify research and analysis tasks to alleviate negative impacts, to augment positive impacts, or to

better understand these impacts. It should strive to develop valuable insights to societal benefits or problems produced by the potential introductions of the technologies and to develop recommendations for research and technology efforts toward improving the impacts. Thus technology assessment studies can provide a broad appreciation of impacts and implementation problems and may contribute to improved research and technology decisions.

Among the earliest beginnings of "the technology assessment concept" are studies by the National Academy of Science and the National Academy of Engineering during the period 1967-1969,[4,5] performed for the U.S. Congressional House Committee on Science and Astronautics. These studies defined the basic concept of technology assessment and outlined a framework for the process. A more detailed and conceptually more refined scheme of the methodology of technology assessment was developed in the White House Office of Science and Technology during the period 1969-1971.[6] Under support from the Office of Science and Technology the Mitre Corporation further improved the techniques and approach.[7] During this period many organizations were performing assessment studies, several of which were sponsored by the National Science Foundation, Office of Research Applied to National Needs (RANN).[8]

Congress developed an early interest in technology assessment which led to the establishment of an Office of Technology Assessment (O.T.A.). The O.T.A. commenced operation in January 1974 and has since been asked by Congress to undertake assessment in a wide variety of areas.[9] Congress sees technology assessment as an aid to legislative policymakers in

anticipating and planning for the consequences of technological changes and in examining the many ways, expected and unexpected, in which technology affects peoples' lives.[10]

Industry has lagged in technology assessment interest, perhaps because of its profit motivation rather than an altruistic interest in the public welfare. However, several notable technology assessments have been industry-sponsored.[11] Public interest groups have, as might be expected, shown interest in such studies[12] but have been limited by their resources. The universities have also maintained an interest in technology assessment,[13] although often directed more toward methodology improvement rather than actual results.

In 1974, NASA broadened its use of technology assessment in an effort to better understand the impacts of the technologies that may emerge from their research and to assist in directing the agency's research and technology program planning toward improving its quality, timeliness and relevance. Technology assessment applied to R&T programs represented a new area of activity for NASA and proved to be a learning experience for the sponsoring offices. To gain an understanding of the methodology, subjects were chosen which were of interest to the Agency. However, they were far enough removed from ongoing programs so that the inevitable learning process would not impair those programs.

With the preceding as background, the purpose of this review is twofold. First, it is to summarize the methodologies that were used in the initial NASA studies. Second, it is to provide others with the

lessons learned through our experience — the do's and the don'ts, and a few suggestions for improving the effectiveness of future technology assessments.

The studies reported in this review were sponsored by the NASA-Ames Research Center and (except for an on-going assessment of cargo aircraft)[14] represent the current technology assessments which were performed within NASA. These include:

- An Assessment of Lighter-Than-Air Technology.[15]
- Technology Assessment of Portable Energy RDT&P.[16]
- Technology Assessment of Future Intercity Passenger Transporation Systems.[17]
- Space Disposal of Nuclear Wastes: Socio-Political Aspects.[18]

Also included is a comment on a recently completed NASA-Ames Research Center sponsored study entitled "Who Should Conduct Aeronautical R&D for the Federal Government,"[19] which describes a new methodology for quantification of subjective analysis. The review will end with a critique which provides a composite understanding derived from the studies and a few suggested recommendations for improving the efficiencies of technology assessment.

SECTION A: AN ASSESSMENT OF LIGHTER-THAN-AIR TECHNOLOGY

Background. Interest in Lighter-Than-Air (LTA) vehicles seems to have a resurgence every decade or so. The present revival reached new highs in national interest during the mid-70s, shortly after the world more widely recognized its limited energy resources. The airship's fuel efficiency and its low noise and pollution levels were considered among its virtues. The airship

has the potential of utilizing inexpensive landing sites and of transporting large bulky cargo; it may well find extended applications in less developed countries. During this most recent period of enthusiasm, the Senate Committee on Aeronautical and Space Sciences heard testimony on various LTA and the NASA awarded study contracts to analyze LTA concepts.

Simultaneously, with renewed interest in the United States, several design projects were started in England, France, Germany and Canada, sponsored by reputable firms (e.g., Shell International). A German firm has built several small airships recently and a Canadian airship is soon to be flown. A British group flew a small recreational vehicle. The Soviet press has announced design studies in progress in the USSR.

Objectives. In light of what seemed to be an emerging technology (or more accurately a revival of previous technology), it was appropriate that an assessment be made of its potential, its impacts, and its requirements. To provide a focus for the many airship activities and a timely forum for the exposition and discussion of current views and ideas, a one-week workshop was planned as a major part of the six-month assessment.

Approach and Highlights of the Methodology. The assessment of LTA Vehicle Technology was jointly sponsored by NASA, the Navy, the U.S. Department of Transportation and the Federal Aviation Administration, which agencies shared in the interest and responsibilities of LTA developments. The Massachusetts Institute of Technology Flight Transportation Laboratory organized and directed the six-month assessment which included a preliminary literature search, a week-long workshop, the documentation of the workshop proceedings and the development of assessment findings and recommendations.

During the first part of the workshop, formal presentations were made to the participants who came from universities, government agencies and the military, manufacturers, airlines and consulting firms. They included government and civil planners, lawyers, engineers, economists, marketing men, ex-airshipman, and the like. After three days of presentations, the workshop participants formed five working groups to discuss the information presented and to apply their own expertise to the various aspects of buoyant flight. Ideally, these groups should have come to preliminary positions and then exchanged members with other groups to cross-pollinate ideas and coordinate results. However, due to time constraints and the large number of topics to be covered, interaction was limited to a few general presentations by each working group to the participants as a whole.

After the workshop the draft reports of the working groups were distributed to all participants for review and comment. The responses were then incorporated into the final report so that hopefully the report represented the consensus of the problems and issues raised by those participating in this assessment.

Technical Results. Complete coverage of the workshop presentations can be found in the Proceedings Report[15] and a detailed discussion of the assessment results can be found in the Assessment Report.[15] A brief summary of the highlights are presented here. A statement of LTA potential was endorsed which declared that Lighter-Than-Air systems have certain inherently attractive characteristics, including:

1. Low dependence on prepared facilities and rights of way.
2. Unique ability to transport large indivisible loads.
3. Unequaled airborne endurance on station and en route.
4. Low fuel consumption and minimal environmental impact.

These characteristics give LTA the potential for solving national and international transportation problems such as opening up inaccessible regions for agriculture, the development of natural resources, on-site delivery of modular housing, large powerplant components, and anti-submarine and surveillance missions for the military. In addition, LTA could supplement current systems for cargo transportation, environmental monitoring and social services, such as disaster relief. Foreign sale of LTA vehicles and components would also help the U.S. balance of payments.

Although LTA systems could provide enormous benefits to the United States and the world, they may cost hundreds of millions of dollars to develop and implement. Therefore, to minimize the technical and economic uncertainties prior to committing such large sums, the following actions were recommended:

1. Technology

   Current technologies in aeronautics and related fields should be surveyed to determine what knowledge may be directly transferable to LTA systems.

   LTA projects in progress or contemplated by foreign governments and companies should be surveyed to identify common areas for international cooperation.

A technology assessment of LTA systems should be performed specifically analyzing comparative energy consumption, land use, noise and air pollution and other environmental impacts for a broad range of LTA applications. (The study group recognized that the current assessment was limited by time and could not conduct an in-depth socioeconomic/political technology assessment.)

LTA analysis should be introduced into academic programs and the theoretical study of LTA encouraged through fellowships and financial aid.

2. Market analysis

A broad survey of unsatisfied transportation needs should be conducted to identify commercial markets and military missions where LTA might offer a unique solution and to estimate the rates at which service would be attractive to consumers.

Cost, volume, service and performance characteristics should be identified for a range of commercial markets and military missions currently served by existing transportation modes, and estimates should be made of what LTA advantages would be required to penetrate these markets.

The transportation problems of developing countries and LTA's potential for solving them should be given separate attention.

3. Government policy

A mechanism for the exchange of information between potential users and potential manufacturers should be established with a central clearinghouse for LTA-related information.

Government agencies should include LTA as an alternative in all future transportation studies.

Appropriate agencies should develop incentives to stimulate broad interest in LTA in the private sector. This could include a program of modest government grants for concept development and elaboration as well as possible cost-sharing programs between government and industry.

Certification, licensing, and operating rules and regulations for LTA vehicles and crews should be reviewed, revised and developed where needed to allow rapid progress in the private sector unhampered by unnecessary technicalities.

The helium conservation program should be reviewed to preserve this rare element that is essential to LTA systems and other technologies as well.

Critique of the Study Process. This study represented the first of a series of technology assessments which are reviewed in this report. By some standards it might not be considered a "technology assessment" (i.e., a study of the socioeconomic/political/environmental impact of a technology). Because of the limited time and resources allotted to this program, it concentrated on the favorable impacts and the political-economic-technological requirements. It was successful in accomplishing these limited goals and did indeed provide a timely and public forum to discuss the question of LTA revival.

The methodology used represented a simple straightforward approach. The preliminary literature search allowed the study team to become

familiar with the subject technology, the leading proponents and opponents and their views. A good mix of disciplines and viewpoints was then invited to present formal papers on a variety of topics. However, the papers were primarily technical reports on design, economics, application and operation of various concepts. There were no formal presentations on possible environmental or social issues related to the introduction of LTA vehicles. Nevertheless, these, as well as political issues, were treated during the working sessions which followed the formal papers.

The feedback mechanisms worked well; the draft report of each working group was sent to all participants for their review and comment. The inclusion of their remarks and second thoughts helped to make the final report representative of the consensus. The study groups recognized the constraints of time and resources available for this effort and therefore endorsed a recommendation that a comprehensive socio-economic/environmental "technology assessment" be conducted.

SECTION B: TECHNOLOGY ASSESSMENT OF PORTABLE ENERGY RDT&P

Background. Shortly after the Mideast oil embargo of 1973, NASA-Ames Research Center sponsored an industry/university team from TRW Systems Group and the University of Texas to undertake a six-month technology assessment of portable energy Research, Development, Technology and Production (RDT&P). The project was to assess the technical, economic, environmental and sociopolitical issues associated with portable energy supply options and to determine those courses of action impacting aviation and intermodal transportation R&T.

Objectives. The objectives of this technology assessment of portable energy RDT&P were: (1) to determine the possible impact of the more promising fuel supply options on the time frame and goals of aviation and intermodal transportation R&T; (2) to evaluate and compare alternative sources of conventional and synthetic portable fuels and their related technologies; and (3) to define critical issues, uncertainties and potential risks associated with the portable energy technology options.

Approach and Highlights of the Methodology. This technology assessment began in June 1974 with the establishment of a primary information base defining alternative portable energy resources and technology; a compilation and assessment of current policies, programs and issues relevant to the development of portable energy; and the generation of six reasonable portable energy scenarios, which were used to scope and focus the agenda for the ensuing interdisciplinary technology assessment workshop held during August. Thirty-eight representatives from industry, government and universities were invited to participate in the workshop, and every effort was made to select participants representing a broad spectrum of viewpoints and disciplines (environmental, sociological, technical, legal, and so on).

The workshop utilized the basic natural process of creative conflict resolution. To do so, the initial activity involved organization of small work groups representing similar disciplines to gain clarity of each position. The conference was then reconfigured into work groups

with members from differing disciplines, in which differences and similarities were fully and explicitly explored. (Conflict often tends to be suppressed so that the real issues stay in a gray area and are never worked through. On the other hand, a clear statement of difference leads to real, integrated solutions which can incorporate many of the best features of each viewpoint.)

An important effect of this approach was that it tended to build commitment to the final outcome in initially antagonistic parties. Real consensus was achieved by holding off premature and usually superficial agreement until each party felt he had been fully heard and his position truly understood (though not necessarily agreed with). The key strategy in the workshop was to continually focus and refocus on the goals and expected results, while bringing to the forefront the viewpoints of the workshop participants as to the most promising alternative fuel approaches to insure adequate supplies, the positive and negative aspects of each approach, and the near-term actions required to implement these approaches. The working group reports cover the above areas of interest as well as conclusions and recommendations.

Following the workshop, independent reviews and analyses of the group reports were undertaken by the NASA, industry, and university teams. The teams coordinated the reviews and published a final report on the results and recommendations of the technology assessment which included identification of these appropriate issues requiring additional in-depth study.

Technical Results. The working groups produced over 80 conclusions, recommendations, and items of interest which were distilled into 47 problem statements as part of the post-workshop phase of the program. Eighteen of these problem statements were of interest to NASA, and 7 of the 18 were particularly relevant to NASA's program interest at that time. Some of the more important areas are summarized in the following paragraphs.

To reach any 1985 goal other than complete collapse, planning for energy production and conservation measures in the coming decades must begin immediately (1974). Even with planning, it is unlikely that we will be able to survive the next decade without a series of crises more pervasive in nature than the gasoline shortages of 1974-1974. These future crises present both opportunities and problems. On the one hand, they will fire public interest in and understanding of the problems and help generate a commitment of national will to solving them; on the other hand, they will shake public confidence in their leaders and will provide forums for foolish behavior where devils are selected and executed. Because of the supply constraints of the next 10 years, our best hope is to understand crisis management so that progress is maximized and foolishness minimized. Although government must play a leadership role, the tasks ahead require a unique cooperative attitude between the public and private sectors. It would be a grave mistake to conclude that energy programs are equivalent to government programs.

The general strategy selected by most participants was to rely heavily upon coal, nuclear energy, oil imports and conservation efforts

for the short term, with a phasing in of new clean-energy technologies during the 90s, including solar, synthetic liquids, geothermal and ultimately fusion. There was considerable debate about the desirability of nuclear power. Many felt that deployment of nuclear fission power plants had to continue through the 80s because the near-term supply picture was so bleak that no option could be ignored. But, because of the public debate concerning several of the safety and physical security aspects of nuclear power, there was substantial feeling that it should grow only to the extent required to make up the energy gap, and new plant construction should be phased out at some period in the 90s as non-fission technologies, particularly nuclear fusion, become available. Because of the difficulties associated with nuclear power in the public's mind, capital may be more difficult to raise. The consensus was that more development should ultimately go into coal-based strategies.

The conclusion was reached that we must accept nuclear power and strip-mining or face the consequences of foregoing the use of the energy that either or both provide. New insight is gained in this last step; while we can estimate the energy loss to the nation, we cannot evaluate the social and economic impact of the loss. This last statement is very important. What do we gain by taking the environmental risks that go along with coal and nuclear power? Are we buying freedom from massive food shortages, unemployment, and economic disaster, or are we simply buying an unnecessarily high level of affluence? A penetrating study

is needed of this critical question before a rational decision on supporting nuclear power can be made.

A final general observation was that many of the strategies suggested for research and development could end in failure. It was recommended that research money be widely spread among a variety of more promising strategies to allow us to select viable options. In present-day terms, this suggests that the nuclear fission technology may be receiving undue emphasis to the detriment of other promising approaches. A nuclear disaster, whether accidental or deliberate, anywhere in the world, could leave us with no contingency plan to fall back upon.

The impact of a crash R&D program on this energy scenario has not been properly evaluated but clearly merits consideration. In general, it was felt that development of technology for utilization of various energy resources (including coal, shale, and solar) is very important to relieve demands on the domestic supply and theat concerted efforts should be made in that direction immediately. However, it was noted that, traditionally, long lead time is required until the industrial infrastructure is built for such new technologies and their commercial delivery. To facilitate such implementation in the future, new technical, legal, managerial, and institutional structures/interfaces may have to be created.

Critique of the Study Process. The first area requiring improvement is a clearer, more specific, and more workable statement of the study

objectives and better advance communications of these objectives to the participants. This would require more discussion at all levels and in-depth identification of what exactly is desired. Two independently negotiated contracts were used to support the individual university and industry efforts. For future projects of this type, joint or coordinated industry/university contracts should be utilized. The concept of using government/industry/university teams to study and recommend action on complex national problems seems promising. In this project, the teams worked together in an efficient and well coordinated manner. However, liaison between participating parties prior to contract award would encourage coordinated proposals and minimize the possibility of unreconcilable project approaches.

It is recommended that the work group chairpersons be thoroughly and explicitly briefed on their roles and responsibilities and on the methodology of the workshop. Considerable effort should be expended to ensure the proper mix and attendance of the participants necessary to meet the workshop objectives. When guest speakers are chosen, much thought should be given to the probable nature of their presentation to ensure a variety of viewpoints. The number of full-time observers should be minimized, and the sponsor representatives should serve as regular group participants rather than as observers. Finally, observers should schedule their visits so that they neither enter nor leave during a workshop session.

Scenarios should be carefully reviewed to stress clarity, precision, and conciseness, and adequate transitional description should be included

to explain how the projected futures came about. Charts, tables, and graphs should be included, as appropriate. If the scenario technique is to be used at a workshop or conference, a short (20 minute) explanation of concepts, procedures, and purposes should be given prior to work group sessions. Similarities and differences between work group plans should be identified. A well structured format for group discussions should be provided and chairmen encouraged to channel group deliberations along these lines.

One important recommendation is to greatly condense and summarize any input data distributed to participants before the workshop. Experience showed that virtually no one read any of the prework before the workshop. Moreover, the material provided was far too detailed for the purpose intended, and little was done to properly summarize what was presented. As a guideline, not more than a dozen pages of information should be distributed prior to the workshop, and should be properly written and summarized for assimilation by busy people. Beyond the prework information, other input data used in the workshop should be much better organized. Emphasis should be on facts rather than on speculations and opinions by people less competent that the participants themselves. It is suggested that some time in the workshop be devoted to "data briefings" by selected participants who are particularly knowledgeable on the subject matter. If written data are provided, time should be allotted in the workshop for reading and studying the material.

Many of the comments in the preceding paragraphs were provided by the participants who had the opportunity to critique the workshop process

at the conclusion of the workshop. These critiques have been summarized as part of the final proceedings report.[16]

SECTION C: TECHNOLOGY ASSESSMENT OF FUTURE INTERCITY PASSENGER TRANSPORTATION SYSTEMS

Background. Completed in March 1976, the technology assessment of intercity transportation systems was sponsored jointly by the National Aeronautics and Space Administration (NASA) and the U.S. Department of Transportation (DOT). The 13-month study considered future transportation systems — air, auto, bus and rail — to the year 2000. The emphasis was on domestic passenger transportation, but interfaces with freight and international transportation were considered. To perform the study, a "technology assessment team" was formed which consisted of a consortium of industry (Peat, Marwick, Mitchell & Co, Gellman Research Associates, and Science Applications, Inc.), university (University of California at Berkeley and Stanford University), and government (NASA-Ames Research Center, NASA Headquarters, U.S. DOT-Office of the Secretary, and U.S. DOT-Transportation Systems Center). A group of additional "study participants" was formed from government, transportation and other industry, and academic institutions to review and contribute to the progress of the study.

Objectives. The purpose of the study was to assess technical, economic, environmental, and sociopolitical issues associated with future intercity passenger transportation systems. A goal of this technology

assessment was to assess the impacts of new transportation technologies on society and to identify potential problems, drawbacks, and advantages of individual technologies. A second goal was to identify research and analysis tasks which alleviate negative impacts and augment positive impacts, and to better understand these impacts.

Approach and Highlights of the Methodology. During the first half of the study, project team members conducted an analysis of intercity transportation system options to the year 2000. Initial tasks of this effort included the identification of issues affecting the future of intercity transportation. Papers were prepared by individuals representing a diverse array of backgrounds and viewpoints in an effort to assemble a substantial collection of discussion material. Forty "outside" participants were selected early in the project; they contributed throughout the study by reviewing draft reports.

The technology identification task of this study focused on the future performance characteristics of present intercity modes and possible new technological forms of transportation. Knowing that there were hundreds of intercity transportation technological forms or variations in which the guideway, suspension, propulsion, energy requirements, pollution, noise, or other characteristics differ, the technology team chose to separate modes into general classes such as air transportation, improved rail passenger transportation, high-speed ground (levitated) transportation, and highway transportation.

Scenarios were used in this study to provide a structure for assessing alternative future transportation technologies and policies.

"Background scenarios" were developed to describe four different states of society in the year 2000. Then, for each background scenario, a "transportation scenario" was developed and analyzed. The scenario descriptions included consideration of how year 2000 intercity transportation systems might evolve from those currently in operation. The characteristics of the assumed transportation systems were generally based on results of the study's technology task, but in some cases more advanced characteristics were postulated. The primary purpose of these extrapolations was to provide for wideranging future possibilities that may result from currently unforeseen technological breakthroughs.

A week-long workshop was held at the midpoint of the 13-month study to review intermediate results and to identify and debate issues and impacts related to future transportation alternatives. The workshop was attended by the project technology assessment team and the 40 outside participants. The workshop was conducted primarily in small working groups termed "assigned panels." Four such panels met several times during the week and followed generally parallel lines of inquiry. The membership of the assigned panels had been established prior to the workshop by the project team to include a variety of viewpoints in each group. Early panel sessions focused on a review and critique of study scenarios but most of the time were devoted to impact assessment. Each panel prepared a report of their deliberations. Time was also allotted at the workshop for "special topic sessions." Potential topics were suggested by study participants and sign-up sheets were used to gauge

interest in holding a session. In each case, where sufficient interest developed, two or three hours were devoted to small group discussion.

Following the workshop, the impact assessment task described consequences that might occur if certain technological developments take place in intercity transportation. These broad-ranging consequences included economic, environmental, social, institutional, energy-related, and transportation service implications.

The final task of the project team and one of the products desired of this study was the development of recommendations on further research and analysis tasks pertaining to the impacts of future intercity transportation technologies. In the judgment of the study team, the highlighted recommendations have high leverage and relate to significant issues or impacts, with important implications for the quality of future intercity transportation; that is, they are believed to offer promising avenues for substantially improving intercity transportation.

Technical Results. Summarized below are a few topic areas for recommendations developed in this study. Additional recommendations and a more thorough explanation and rationale for these may be found in the final report.[17]

- A greatly expanded program of research and technology development for propulsion systems and vehicle design with the objective of improving fuel-efficient and nonpolluting alternatives to the present automobile. A key to the expanded program is careful coordination of publicly supported efforts and automobile manufacturers' efforts. Public efforts should emphasize high-

risk research and monitoring the rate of technological improvements in energy efficiency in order to advise control agencies when more exacting pollution standards and fuel-economy standards should be applied.

- Aircraft research and technology emphasizing developments leading to reduced cost, fuel consumption, and noise. Among these are improved airfoils, composite materials (including demonstration of use of large composite structures), propulsion improvements, reduction of other (nonengine) sources of noise (i.e., aerodynamic noise), and active controls.
- A study of mechanisms for introducing new aircraft technology into commercial use. (The study should include an appraisal of government financial, tax, and regulatory policies to encourage more rapid implementation.) For example, an assessment should be undertaken on the current program to develop quiet aircraft engines. The study should evaluate not only environmental impacts on a national scale but also the economic impact on engine manufacturers and financial constraints that the airlines might face in attempting to acquire the technology on a priority basis.
- Systems analyses of changes in aircraft scheduling, routing, and operations. The aim of these studies should be to reduce costs and fuel consumption while maintaining acceptable service levels. A range of future aircraft sizes and technologies, as well as the impact of changes in industry regulations should be considered.

- Expanded scope for ongoing STOL aircraft technology efforts to include short runway aircraft (SRA) systems. The SRA systems would use longer (3000- to 5000-foot) runways than STOL at existing or new satellite airports. The availability of satellite airport sites — closer to larger population centers than existing major airports — requires investigation.
- A program to identify and test means of improving intercity bus service. The program should explore possible vehicle changes such as wider buses. A series of case studies should expand on existing research knowledge to improve bus transportation, such as seeking innovative ways to improve bus stations and to provide better integration of bus services with those of other modes. In direct support of these studies, an evaluation is needed of public attitudes and user choice factors influencing bus patronage.
- An analysis of the benefits and costs of existing AMTRAK services. Data need to be analyzed on a systemwide as well as route-by-route basis, in relation to other modes, to assist in decision-making on changes to the AMTRAK route structure and the desirability of continuing government subsidy.
- Technology and systems evaluations of improved passenger train service. Efforts should focus on ways to implement service as soon as practical on appropriate routes to capture potential energy savings. Questions related to noise, safety, and interactions with freight service need to be addressed in specific rail corridors.

- Tracked levitated vehicle (TLV) research studies to address currently perceived negative impacts of the technology. These concerns include high guideway construction costs, noise, and safety. Vehicle and guideway technology studies for TLV are of a high-risk nature but component research should be undertaken to understand and perhaps resolve systems impact problems.
- A study to resolve uncertainties on features of future generations of the air traffic control (ATC) system. This study should be based on a comprehensive review of the effectiveness and costs of components of the Upgraded Third Generation Air Traffic Control (ATC) System.
- A program of airport landside research, closely coordinated with ongoing airside work. The objective of the program would be to develop planning methodology and guidelines for airport landside improvements. Case studies of a number of representative airports should be undertaken, evaluating passenger and baggage processing improvements, both in capacity and efficiency.
- A technical study to identify and evaluate electric/automated highway system options. The study should develop data on technical and economic feasibility for alternative propulsion and control subsystems and on the power generation and transmission implications of widespread implementation. Development might be pursued to the stage of small-scale "laboratory" demonstrations of performance.

- A continuing program of study and experimentation to improve access/egress and intermodal transfer for all intercity modes. The program should include study of the inexpensive changes to urban public transport services and vehicles to help meet intercity traveler requirements, terminal design and location options, and analysis of effective means to disseminate travel information. Reviews of recent studies of multimodal terminals should be undertaken to identify the major roadblocks to successful implementation. For the most part, this program should be case-specific (and conducted locally in cooperation with state and local governments and private operators), although a search for problem commonalities among different urban areas should be emphasized.

Additional topic areas in abbreviated form follow:

- Research on new construction materials for transportation vehicles, with techniques for disposal and recycling of these materials as an integral concern.
- Studies to develop improved information on traveler preferences, including the importance of comfort, convenience, and personal security relative to perceived cost and travel time.
- An expanded and more detailed data base on intercity travel by origination-destination city-pair.
- Improved estimates of the short- and long-term financing requirements of intercity transportation modes.

- Funding mechanisms for transportation system maintenance and improvement that accommodate technology substitution and that use public funds to stimulate private investment.
- Methods to appraise the impacts of institutional forces on technology delivery (methods comparable to those used in preparing environmental impact statements).
- Improved techniques to analyze the effects of alternative economic, environmental, and safety regulations on levels of intercity service, transport industry structure, and technology development and implementation.

Critique of the Study Process. Because of the study's very broad topic, it was difficult to define specific issues by sharp definitive statements. In order to have some bounds on the project, it was necessary to occasionally review and change the focus of study activities. A short time into the study it was obvious that items in the initial scope, such as time-frames beyond 25 years and freight transportation, could receive only minimal attention, while the bulk of the effort would be on domestic passenger transportation within the next two decades. Even so, the assessment of future transportation impacts was often vague and of limited depth. This may have been due partly to the absence of a defined technology at the start of the study. Although the literature abounds with future transportation technologies, no specific technologies were singled out for study focus. In retrospect, the analysis may have led to greater depth and more meaningful assessment if limited to fewer modes and fewer travel markets. (These restrictions were considered

before the study but discounted, since one main goal of the assessment was to overcome the limited applicability of previous "corridor" studies which promoted a single mode.) In the future, before a large technology assessment is undertaken, consideration should be given to performing a preliminary short study or mini-assessment to focus on a set of specific and realistic objectives that can be accomplished within funding time limitations.

It should be noted that this study, because of an awareness of the previous two studies, avoided some of their deficiencies, but nevertheless encountered new difficulties. Admittedly this technology assessment was quite broad, but the scope had been carefully defined at the outset. It would have helped, however, to allow flexibility in project time schedules and resource allocation plans (both of which are difficult to float in a government contract). The nature of a technology assessment is to deal with unanticipated impacts, and, accordingly, this may uncover new areas that were not identified in earlier project planning or expand areas that become more important than initially anticipated. If possible, provisions for such flexibility should be provided in subsequent large scale technology assessments.

Due to the unique consortium arrangement of the performer/sponsor teams (three industry organizations, two universities, and four government offices), there was ample interdisciplinary participation, with wide-ranging viewpoints. This led, however, to large amounts of documentation, making extensive reading necessary for a comprehensive understanding of overall issues. Then, too, all documentation was distributed to the 40

outside study participants for their review and comment. The mailing and subsequent review of responses was quite burdensome. Although the material was read by everyone, it was generally agreed that the amount and frequency of material mailed to study participants should be carefully selected and limited.

The workshop used in this study seemed to accomplish its purpose, although there may have been some wasted effort the first day and a half during which scenarios were treated. This was the second study in which the sponsors used several scenarios to stimulate discussion among the invited workshop participants. Although the purpose of the scenarios was explained, the participants nevertheless either rejected them out-of-hand or embraced their "favorite" future. The scenario concept is an area that needs a good deal more planning and a different approach.

With the involvement of three industry groups, two universities, and four government offices, there was the possibility of poor communication and information gaps among the various performers and sponsors. This did not happen because a computer-conferencing network was set up across the nine participating groups; computer-typewriter terminals using a readily comprehended program were available to all the groups. The system was used daily to converse with all industry/university/government members.

An impressive list of findings and recommendations covering all phases of transportation resulted from this particular assessment. However, the process of going from the identified issues and impacts to recommendations which the sponsoring agencies could support can be a

difficult one. This was also true in the previous assessment studies, and it is therefore suggested that this process be reexamined and given major consideration in the early planning stages of a technology assessment. As difficult as it is to define recommendations, it would be even more difficult and perhaps presumptuous to prioritize them. It is anticipated that a technology assessment will be one more management tool to assist in establishing research and technology priorities. However, no one study can possibly identify and analyze all the impacts accrued from the implementation of a technology, nor can it be aware of all the management decisions and priorities that exist at the level of the sponsoring office or higher. Hence, the results of a technology assessment can be used to assist in the development of R&D priorities but should not, within the study, attempt to set these priorities.

SECTION D: TECHNOLOGY ASSESSMENT OF SPACE DISPOSAL OF RADIOACTIVE NUCLEAR WASTE

Background. The first phase of a technology assessment of the possible use of space for the disposal of radioactive nuclear waste was conducted between July 1975 and July 1976. At the time of the study the question of radioactive nuclear waste disposal became — and continues to be — a major public issue in the future use of commercial nuclear power to supply electrical energy. Two previous studies — one by NASA-Lewis Research Center, which considered the technical feasibility of the use of space disposal, and a second by Battelle Pacific Northwest Laboratory,

which examined various alternative methods of disposal — formed the background and starting point for the study.

Objectives. The overall purpose of the three-phased study was to provide NASA with information that would help to decide (1) if the development of a capability of space disposal of radioactive waste material was operationally feasible, safe, and cost effective; and (2) if an extensive research and development program to provide the foundation for such a development was in the best interest of the country. The study was to concentrate on the overall appraisal of the space disposal option rather than on the advocacy or condemnation of such technology. The study was to support and complement studies of other alternatives being carried out by ERDA.

Approach and Highlights of the Methodology. To perform the study, a small interdisciplinary group of three staff members plus a graduate student was formed through a NASA-Ames/University Agreement with the Institute of Governmental Studies at the University of California at Berkeley. This technology assessment team was to explore the social, political, environmental and technical issues with access to individuals from NASA, ERDA, and other appropriate sources.

The assessment was structured into three sequential study phases, each of which was to provide a basis and rationale for going on to the next study. If the results of one phase indicated that the approach or particular technology was not in the best interest of the country, the assessment program was to be ended and any subsequent phases would not be carried out.

The first phase was to assess the broad physical magnitude of the problem and the technological "state-of-the-art" and to place the entire issue in perspective in terms of the moral, social, and political issues involved. In phase two, the ability of the space disposal option to contribute to the solution and the possible impacts, risks, and social benefits would be examined in detail. In the third and final phase the operational technology requirements and the economic commitment were to be examined. At the time of this writing, only the first phase has been completed, with the second phase currently under way with a different study team. Some of the specific objectives of this first phase included:

(1) A thorough appraisal and review of the potential amount of radioactive waste, its composition, physical form and location, estimated production rate, and any requirements for additional reprocessing, partitioning or fixation that would be required. Much of the work was a continuation or extension of work previously done by ERDA and Battelle.

(2) Since space disposal, because of payload restrictions, would of necessity be limited principally to management of the transuranic nuclides with long half-lives, it was necessary to examine the separation or partitioning technology with regard to its expected state of development over the time span of interest.

(3) Finally, the study was to assess the problems that would be encountered in the introduction of such a new and unique technology, with

- special emphasis on impacts that might be unintended, indirect or delayed.

Technical Results. In general, the university team's conclusions were negative regarding the probability and impact of space disposal operations, as can be seen in the following paragraphs.

Given the space technology stipulated for this study, it is not technically feasible for all spent nuclear fuel to be ejected from the surface of the earth; therefore, a sizeable portion of the radioactive waste must remain on earth. First, the spent nuclear fuel must be chemically reprocessed to separate the waste products from the bulk of the inactive heavy metal. Then the wastes must be chemically or physically partitioned to separate the long-lived transuranic products from the short-lived (<1000 year) fission products. The decision to partition is unlikely to occur unless a superordinating decision to go to space disposal is made.

A decision to go to space disposal is not likely to be made at the tail end of the fuel cycle or as an afterthought if other methods prove not to be implementable. A careful prior decision would have to be made to choose this option and to manage the entire fuel cycle in a manner that facilitated it. Past and current policy climate in the federal government leads to the conclusion that the consideration of such a comprehensive and interlocking set of policy decisions is unlikely, even if space were clearly the most favorable way to go.

NASA operations that are highly visible to the public are also those which explore a frontier, and a finite failure risk is tolerated. The

public and the Congress may be willing to write off failures or errors as part of the cost of advanced technological exploration. Clearly, this would not be true for disposal operations.

It was concluded that, even if all other conditions for space disposal were met, the management and operation of such an extensive program would be a risk-strewn and possibly inappropriate role for NASA. The agency would lay its credibility and public confidence on the line if it were to engage in waste disposal operations.

Critique of the Study Process. A technology assessment should be tailormade to fit the resources, timing, and need of the decisionmakers. In this case, the study was to broaden the information base for decisionmaking and long-range NASA planning. To perform this function a technology assessment should possess certain structural elements: description of the technology; definition of the issues, their current status, and probable future course; identify policy actions; suggested alternative policy scenarios; and assessment of the complete spectrum of potential impacts. The previous study carried out by NASA-Lewis was largely an in-house NASA effort. As pointed out by Dr. Don Cash, Director of the Science and Public Policy Program at the University of Oklahoma, "such studies are open to serious challenge because of possible promotional interests and their credibility may be questioned." To avoid this possible stigma, almost complete independence was maintained between NASA and the study team. One consequence of this was that the University study team had difficulty obtaining sufficient technical information concerning the space shuttle operations on which to base their social and political

evaluation. In most cases such information was not readily available, but, in any case, it certainly could not be obtained by an "arm length" posture with the sponsors. The institute group found that the apparent lack of hard technical information makes a social or political interpretation at best difficult, if not impossible.

Several factors are essential for a successful in-depth technology assessment involving social impacts beyond the primary effects:[20] (1) the technology being assessed should be understood fully and completely (in the present study the details of this technology were conceptual and not well-defined); (2) completeness and balance in a technology assessment requires a diversity of inputs; and (3) independent outside review is necessary to produce a credible study of high quality. Restrictions in time, money, manpower and a lack of understanding of the probable future space and nuclear technological capabilities made these factors difficult to meet during this study. Accordingly, it is hard to interpret its impact, if any, on NASA decision making.

As pointed out by Selwyn Enzer,[21] one of the most difficult issues in any technology assessment is the degree to which the assessment team should make value judgments and policy recommendations. This is due partly to the unscientific nature of such evaluations and partly to the struggle to preserve the sense of objectivity that such studies are supposed to have. There are several degrees of an assessment, each appropriate at a different stage. A bit of hindsight and a broad review of the study suggests that the policy recommendations are perhaps premature and that the social/political analysis should have been delayed

until a fuller understanding of the technological and economic aspects are in hand. The study sponsors had thought it possible to assess the sociopolitical impact of a technology without an exhaustive knowledge of the characteristics of that technology, but evidently it was not possible. Only a first appraisal of the magnitude of the problem was desired by NASA, whereas the university team attempted to perform an in-depth sociopolitical impact study of a technology application that was incompletely defined from a technical and operational standpoint.

The sponsors of this space disposal study concluded that a final judgment of the appropriateness of space disposal should be made only after the second and third phases are carried out and then compared with other technical alternatives on an equal basis. Such analysis is now under way.

CRITIQUE OF ALL PROJECTS

In the preceding sections, a synopsis was presented of each of the technology assessments conducted by the NASA-Ames Research Center. Those who wish to see an in-depth development of the technical results and recommendations of any of the reviewed studies are encouraged to obtain a copy of the referenced final reports.

At this writing, it has been one year since the completion of the last assessment study reported herein. The authors agree that this length of time was necessary before an objective review could begin. Indeed, it is suggested that a study can never be reviewed wholly objectively by its sponsors. Nevertheless, most practitioners of technology assessment seem compelled to write about their experiences. Many of

the favorable and unfavorable aspects of each of the technology assessments have already been identified, hence they will not be repeated here individually except to provide a composite understanding of particular study techniques. In the following paragraphs, broader aspects of the technology assessment process are discussed with the expectation that these findings may be applicable to most assessment studies.

Purpose of the Technology Assessment. The objectives of a technology assessment should be very clearly defined to all those involved in the study, a point which cannot be emphasized strongly enough. The purpose of the study and the relationship of the study to the sponsoring office must be realistically appraised. The purpose of the assessment should be known at the start of the study by the technology assessment team and all outside contributors (i.e., participants external to the immediate contractual study members).

Breadth of Assessment Team. A wide range of views on the technology assessed will lead to a more comprehensive and objective study. It can also lengthen the time required to assess the issues and impacts, but the study will benefit. The technology assessment team should not be isolated from outside viewpoints but should seek them. For this reason, the use of consortium teams comprised of university and industry members may be advantageous. It is the rare organization that can assemble a comprehensive multidisciplinary group within its own employees to work on a specific task. Although a company or university may have sociologists, economists, political scientists, environmentalists, technologists, etc., it may be unable to assign them

to a study outside their department because of existing institutional barriers. It is often easier to subcontract for the required discipline coverage.

Cosponsors. Most technologies are under review by more than one government agency, and the implementation of that technology will most certainly impact two or more agencies. For this reason two of the technology assessment studies were sponsored by more than one federal agency. This seemed to provide greater breadth in the treatment of the technology and its impacts as well as gain wider interest and support in the study. However, there is an additional burden on the sponsors and performers to insure adequate coordination and communications across several offices and organizations. The result is undoubtedly worth the effort and closer ties are established between agencies at an earlier phase of a technology's emergence.

Limitations of Technology Assessment. There are, of course, many limitations to technology assessment, and they should be recognized by both the sponsor of such a study and anyone who might review the results. Principally, technology assessment does not make decisions for you; rather it provides additional options, insights and understanding to the problem at hand and recommendations toward their solution. It should not be the only instrument on which the decision-maker relies, nor should it be considered the final word since predictive accuracy is often uncertain. This may be due to an inadequate data base, a lack of imagination on parts of the study team, the inability to foresee all possible impacts, or the personal bias of the assessors or of the sponsors. Additionally, the reports tend to be lengthy and wordy with few interesting graphics

and are, consequently, very often not read at length. Because of the methodical nature of technology assessment, they tend to be time-consuming and should not be used for a rapid response decision. They are often too broad in their technology coverage while being too narrow in their treatment of the socioeconomic/political issues. Lastly, it is often quite costly to perform a comprehensive technology assessment.

"Outside" Contributors. As discussed in the introduction, the methodology of technology assessment has undergone continuous change so that no one generally accepted technique exists. The approach used should be geared to the subject matter, resources available and objectives of the sponsors. Recognizing the need for a spectrum of viewpoints on complex technology issues, a conscious effort was made to incorporate into the studies the broad perspectives available through "outside" participants (i.e., external to the immediate contractual technology assessment team).

Technology assessments which include "outside" contributors can increase the objectivity of the study as well as provide a variety of viewpoints and disciplines to give focus to the important issues and impacts under consideration. A balance between advocates and opponents and a proper mix of disciplines from appropriate public and private sectors will provide much-needed objectivity. "Outside" contributors should be identified early in the study and used throughout the assessment. In the first three studies reviewed in this report, an effort was made to work with the "outside" contributors throughout most of the 6- to 13-month study durations. These "outside" members were considered

an integral part of the assessment process and were expected to actively participate in the development of the study findings and recommendations.

Some question exists regarding the type of "outside" contributor who will best serve the objectives of the study. On the one hand, staff-level, energetic junior people can provide a source of fresh ideas and unconstrained vistas. They also have the time to explore a wide range of issues. However, this category of personnel generally have less experience to give to the study, although they themselves may benefit from the learning experience. Additionally, because of their staff position, they may be unable to effect any change or implement any suggestions gleaned from the assessment. On the other hand, administrative-level, senior people may impart considerable experience and wisdom; this category of participant can not only endorse a study recommendation but make it happen. However, they are often set in their ways and may not provide needed flexibility on subjective issues or new approaches to age-old problems. Also, because of the many demands on senior-level people, the time they can devote to the assessment is often limited. Perhaps a good balance may be found in middle-management people. This group has good experience and is often looking for and offering suggestions which may be new and untried but well-reasoned.

Input to Study Participants. Without a doubt, the most useful input to both internal team members and "outside" contributors is a clear concise statement of the objectives of the assessment. A well-reasoned study purpose and goals will provide a good foundation on which the participants can build.

Another consideration common to all large assessment studies is how to cope with the large amount of reading material sent to the participants. In the case of "outside" contributors, little of the material will be read if it represents a major assignment. In light of this fact, it is suggested that any material earmarked for participants should be carefully reviewed by the technology assessment team and the sponsors with a view toward reducing the quantity to about 20 pages or less. This material should be well organized into small packets of perhaps one to three pages that deal with the specific information to be transmitted. Advanced communications techniques, such as a network of desk-stationed computer terminals linked by phone line, might also be used to maximize communications among groups that are dispersed in terms of geography and interests. This technique was found to be beneficial in the transportation assessment which had team members located in four government offices, two universities, and three private companies widely separated geographically.[22]

Objectivity in the Study. Conducting a technology assessment can be an emotional experience for those involved and results in a closer relationship between sponsor and performer than exists in other study types. This may be due to several reasons: 1) at this stage of technology assessment development, most performers and sponsors are still learning the techniques and depend on each other; 2) the many different disciplines required in a comprehensive assessment and the many impact areas that require investigation dictate close coordination and supervision; 3) the important issues in the study are generally very real and

controversial, and often both the sponsor and the performer can identify with these issues. This suggests that perhaps the sponsors of a technology might not be the most suitable sponsors of an assessment of that technology. On the one hand, the sponsoring office may feel pressures, either real or imagined, to encourage favorable treatment of the agency's technology. On the other hand, the contractor/performer may provide less than candid criticism of the agency's technology in the expectation of receiving follow-on contracts. Incorporating the views of "outside" contributors can provide a large measure of objectivity, and this was actively pursued in three of the reviewed assessments.

Follow-Up to A Technology Assessment. At the time a technology assessment is conducted certain issues will be the topic of general discussion. Contemporary examples include future energy availability and prospects for regulatory reform. The currently "popular" issues are likely to receive a great deal of attention in the technology assessment and heavily influence results. As time passes, the issues may prove less (or more) critical than anticipated during the technology assessment. Therefore, to the extent that technology assessment results are used in formulating R&D plans and programs, these results should be regularly reviewed and modified on the basis of changing conditions. Consideration should be given to the conduct of a follow-up assessment of equal magnitude and scope to its predecessor. Indeed, it may be worthwhile to devise some way in which the original participants could be used as a group in the months and years following an assessment. This idea has also been

suggested by many participants. After an intensive technology assessment, those involved have gained an excellent perspective of the issues and impacts; they therefore represent an invaluable resource. Rather than allow this knowledgeable group to disband, some mechanism should be found to actively work with them periodically and to encourage them to be part of the study follow-up activities.

Balance Within a Technology Assessment. The emphasis in technology assessment is largely on the impacts of the technology rather than on the technology per se. Additionally, there is an apparent tendency to focus on negative attributes and uncertainties regarding technological innovations rather than on positive impacts. Therefore, care should be taken to assure that the social considerations of an assessment are balanced by factors included in more conventional analyses of a technology, including those associated with efficiency criteria and market behavior. This is particularly important in order to ameliorate the anxiety that organizational managements sometimes experience about technology assessment studies. Often, assessment studies produce a less than adequate number of concrete results, and, where recommendations are forthcoming, an agency's "oxes may be gored." Technology managers often exhibit apathy towards social, political, and environmental results, because they naturally feel comfortable with good, hard technological analyses. Comprehensive structuring of the study scope and balanced selection of team members and participants will help achieve impartiality.

Output of the Study. The principal output of a technology assessment will most likely be in the written form of a final report. Herein lies a major failing of many otherwise excellent assessments: the final report is just too voluminous to read for anyone who has the power to implement the recommendations. Because a comprehensive assessment will cover many varied areas, there will be much to report. However, the in-depth coverage of the scope, methodology, impacts, issues, findings and recommendations should be contained in a separate volume, and a very brief summary of these topics should be published in a "stand-alone" Executive Summary of not more than about 25 pages. In addition to a brief and concise summary report, the output of the study should address the method of communicating complex problems and analyses to nontechnically oriented policymakers and to the lay public.[23] Various media should be considered, including audiovisual presentations, documentary film reports, educational television broadcasts, policy-capturing scenarios, pictorial pamphlets, interactive computer graphics and game simulations.

One reason to have "outside" contributors to a technology assessment is to have them learn from the experience so that they may implement some change within their organizations. The primary reasons, however, are generally to provide objectivity and breadth and to contribute to the written output of the study. This can be achieved by requiring written briefs, report critiques, and questionnaire responses. Due dates must be adhered to so that their responses will be incorporated in the study reports. Some incentive must be present to insure a timely output

from participants who are probably already heavily committed to organizational workloads. In the case of the Lighter-Than-Air study, the predominant incentive seemed to be nostalgia since the majority of participants worked with great enthusiasm with no remuneration. The participant critique and response of the Portable Fuels draft report was dismal even though the energy crisis was freshly upon us. In this case, there had been financial reimbursement for the participants only while they attended a week-long workshop. However, with no such incentive upon return to their organizations, they naturally resumed their heavy commitments and ignored the critique of the draft report. In the case of the Intercity Transportation assessment the participants received stipends during a large portion of the year-long study. As expected, most material on issues, impacts, technology characteristics, findings and draft reports were reviewed and commented on in a reasonable and timely fashion. The combination of university grants and temporary personnel assignments used to support the Nuclear Waste study did not contain firm commitments to due dates and documentation requirements, and delivery of the final report was delayed accordingly.

The Use of Workshops in Technology Assessment. As discussed previously, there is no universal technique in technology assessment. The use of "outside" contributors was found to be beneficial to the studies, however, it greatly increased the workload of the contractor team due to the enormous communications, both written and telephone, required to effect a good interchange of ideas and inputs. On those three studies which used "outside" contributors, an additional facet of a one-week workshop provided an intensive focus and real-time feedback on important

areas of the assessment. Workshops provide an opportunity to review the direction and progress of the assessment which may lead to worthwhile changes in the emphasis placed on particular study areas. They may also suggest study areas not previously identified. Participants at the workshop may include the "internal" technology assessment working group either as a separate entity or accompanied by invited "external" participants. There may be times when the working groups would do well to isolate themselves in order to efficiently collect their thoughts and positions and to draft reports. However, care must be taken that the internal group does not merely endorse its own views.

Workshops should be structured to accomplish a particular objective. Each day should be planned in advance and should be a building block in the fulfillment of the workshop goals. Of course, some time blocks should be allotted to extemporaneous topics. Such a degree of flexibility will also accommodate possible contingencies that may occur. Unlike conferences at which the attendees have a passive role, workshops should define working groups in which all participants can have an active role.

Toward the latter part of a workshop, the working groups should discuss and synthesize the information and proceedings of the early part of the workshop. After adding their views and experience, they would produce a written report documenting their discussions and conclusions. (One main difference between a typical conference and a workshop is the written output.) After some editing by the project director, the written reports of the various working groups should be distributed to all the participants for review and comment. The draft reports would be revised

to reflect participant feedback, thereby ensuring that the final report represents the consensus of the issues and impacts raised at the workshop.

Since it is often difficult to extract definitive results from widely differing participant opinions, there will always exist some coloration to the findings. This is an area which requires more theoretical study. Mechanisms such as the tributary technique discussed in the appendix may aid in quantifying otherwise subjective analyses.

Professor Joseph Vittek, now at the Franklin Pierce Law School, provides some insight to the workshop phenomenon:[15]

> "An important element of any workshop is the human chemistry that takes place during the program. After several days, the participants begin to shed their institutional personalities and react with the other participants on a more individual basis. Organizational barriers are lessened and eventually the person across the table is no longer a potential adversary from another company or agency. To aid this interaction, a remote but attractive site is chosen. Participants are isolated from the day-to-day pressures of their offices and normal way of life so they can concentrate on the specific problem at hand.
>
> "The bringing together of people with different and often conflicting interests and opinions in a manner that allows fuller, freer interchange may be the most important though least tangible, accomplishment of a workshop. Most participants

leave with a better understanding of the issues and a better perspective of the overall problems. The effects of this information exchange may not be felt, people will probably no longer connect them with the workshop. But in the long run, the impact of a workshop may have far-reaching effects."

The workshop concept appears to have potential for bridging the "communications gap" among disciplines. In general, the most difficult problems are to focus workshop debates and then to document these deliberations in a complete and concise manner. Continued study of and experimentation with the organization and conduct of workshops appears warranted. In particular, a better understanding is needed on what group deliberations can be expected to achieve. Consensus positions can be one outcome of workshops and these can be of value in supporting or redirecting study efforts. On the other hand, consensus can be sterile for purposes of a technology assessment. The prominent impacts that may actually accrue from an innovation might not be anticipated by a significant number of participants in a technology assessment.

Concluding Remarks. Technology assessment is still in the growing stages of becoming a useful management tool. Although there remain several areas in need of improvement, it has already developed into a significant policy aid in less than a decade. At the very least, technology assessment can help identify what is known and unknown relative to a technology and its impacts. The process generally succeeds in better organizing uncertainties and may provide some estimate of the extent to which the unknown is tractable to further research. Robert E. Gooch phrased this aspect quite well:[24]

"Although technology assessment is far from being perfect, it is definitely better than mere intuition or guesswork. Even considering the limitations of technology assessment, it does give the decision-maker an idea of the possible consequences that various alternative designs may produce. Hopefully, the use of technology assessment, a systematic attempt to 'look before we leap,' will result in better governmental decisions."

The conduct of the technology assessments reviewed in this report have provided a learning experience and knowledge base well worth the effort. As other agencies and government offices implement assessment studies, the techniques will be enhanced and the public will benefit from a wider acceptance and applicability of the results.

APPENDIX: A METHOD OF QUANTIFYING OPINIONS

There are studies in which a quantification of the prevailing opinion would assist in determining relative values and priorities among several options. Of course, in a technology assessment, it is often the minority opinion that will uncover an unsuspecting impact. Nevertheless, it is a difficult task to assign numerical weights to subjective opinions.

A recent study by H. Harvey Album, jointly sponsored by Ames Research Center[19] and the NSF, utilized a new methodology which others may find useful in quantifying opinions. This method, titled the "Tributary Technique" was used in a study of "Who Should Conduct Aeronautical R&D for the Federal Government?". As the title suggests, there

was the possibility of a great deal of subjective opinion, often diverse. The tributary technique was devised during this investigation in order to stimulate discussion, improve communications, and extract quantitative information from group consensus judgments on highly controversial topics.

A total of 25 of the nation's leaders in aeronautical R&D participated in the study. There were five leaders from each of the five main types of aeronautical R&D institutions in the United States: manufacturing companies, service R&D companies, nonprofit R&D institutions, universities, and government laboratories. These participants assembled for a one-day workshop at which the tributary technique was employed. The following is a description of the steps used in this process.

Step I: Homogeneous Group Sessions. The participants were divided into five subgroups. Each subgroup consisted of representatives of a single segment of the aeronautical R&D community; i.e., manufacturing companies, service R&D companies, nonprofit R&D institutions, universities, and government laboratories. These homogeneous subgroups met in separate rooms.

A. Rationale development and self-justification. Each subgroup was asked to agree and indicate, on a flip chart, as many as four primary reasons why the Federal Government should use its type of R&D institution to conduct each category of aeronautical R&D (i.e., basic research, applied research, technology advancements or development). Each statement of rationale was to be a sentence that contained a single reason.

B. Rotation, review, and expansion of rationale. The subgroups then sequentially rotated rooms for each of the following sessions. Each reviewing group read the rationale statements left on the flip chart by the prior groups. The first task assigned to each review group was to enter on the flip chart new statements that either supported, clarified, or corrected the previous rationale for government use of the R&D institution that had initially occupied the room. When four out of five members of a review group considered any of the rationale to be completely invalid, a recorder then noted it by placing a black ball (•) on hand-held rationale sheets.

Step 2: Feedback On Rationale. The rationale statements and judgments from all the prior homogeneous subgroup sessions were next distributed to all participants at a general session. The particpants were then given instructions for the mixed group sessions which followed.

Step 3: Mixed Group Meetings. The participants were then divided into five mixed groups. Every mixed group had one person from each of the five segments of the aeronautical R&D community. These groups each considered a different category of work: basic research, applied research, technology advancement, development, and a combination of these. Each mixed group reviewed all of the rationale statements and group judgments that pertained to work by all five aeronautical R&D institutions within the one work category.

A. Rankings of rationale. The mixed groups first ranked, in order of importance, the rationale statements supporting a particular category of work by each segment of the aeronautical R&D

community. The rankings for all groups were from 1 (highest) to 5 (lowest). Statements could also be rated below the numerically ranked items by leaving blanks. Rankings had to be approved by three or more members of a mixed group. A mixed group could indicate that statements were invalid when four out of the five members agreed to it (•). A mixed group could also add new statements of rationale, as had been done in the earlier sessions.

B. Distribution of work. The mixed groups then formulated quantitative judgments of how deeply each segment of the aeronautical R&D community should be engaged in each given category of aeronautical R&D for the government. Each group arrived at a consensus regarding a reasonable percentage distribution of federal expenditures among the various segments of the aeronautical R&D community for each category of work. These determinations were intended not to represent specific recommended numerical constraints but to reflect roughly the extent of the relative roles of the various institutions in view of the rationale that had just been considered.

Step 4: Individual Evaluations and Feedback. A general session was then held for all participants. The chairman read each mixed group's rankings of rationale. The participants duplicated these rankings onto their copies of the hand-held rationale sheets. (Album suggested that this means of feedback probably could have been handled more efficiently by reproducing and distributing these tables.) The participants then considered all prior judgments and individually ranked the relative

importance of the rationale statements in the left-hand column of their own hand-held rationale sheets. The chairman then displayed the mixed group's work distribution. The participants then individually entered their own evaluations of relative work distribution on special tables provided to each individual.

At the end of the workshop, the participants were instructed to code their written evaluation sheets in a manner that clearly guaranteed anonymity. (Album indicated that it would have been better to do the coding at the beginning of this session rather than to postpone it to the end.) The technique worked well in securing subjective judgments from these groups which had intrinsically competitive objectives, unequal power over each other, and a degree of mutual dependence. The results indicated that there was statistically significant agreement among the total group of all participants on 96 percent of their judgments. It should be noted that this workshop was only one day in length. Such mechanistic approaches as the tributary technique may become bothersome if applied repeatedly, so the key to the success of this technique may be its one-time, quick-action imposition on the unsuspecting participants.

REFERENCES

1) Vary T. Coates, "Technology and Public Policy — The Process Of Technology Assessment In The Federal Government," The George Washington University, Washington, D.C., April 1972.

2) Gabor Strasser, "Technology Assessment....What's In A Name?", Office Of Science And Technology, Executive Office Of The President, published in The Futurist, December 1971.

3) Joseph F. Coates, "Technology Assessment: The Benefits....The Costs.... The Consequences," Exploratory Research And Assessment Office, NSF, published in The Futurist, December 1971.

4) U.S. Congress House Committee On Science And Astronautics, "Technology: Processes Of Assessment And Choice," report of The National Academy of Sciences, Washington, D.C., July 1969.

5) U.S. Congress House Committee On Science and Astronautics, "A Study of Technology Assessment," report of The Committee on Public Engineering Policy, National Academy of Engineering, Washington, D.C., July 1969.

6) Gabor Strasser, "Developing A Technology Assessment Capability," Working Paper, Office of Science and Technology, Executive Office Of The President, Washington, D.C., May 1970.

7) The Mitre Corporation, "A Technology Assessment Methodology," Office of Science and Technology, Executive Office Of The President, Washington, D.C., June 1971.

8) Martin V. Jones, "A Comparative State-Of-The-Art Review Of Selected U.S. Technology Assessment Studies," The Mitre Corporation, report M73-62, May 1973.

9) Office Of Technology Assessment, "Annual Report To The Congress," March 15, 1977.

10) Office Of Technology Assessment, "Fact Sheet," O.T.A., Congress Of The United States. January 1978.

11) M. Breslow, N. Brush, F. Giggey, C. Urmson, "A Survey Of Technology Assessment Today," Peat Marwick, Mitchell & Co., sponsored by National Science Foundation, June 1972.

12) International Research and Technology, "Resource Allocation And Technology Alternatives," sponsored by Resources For The Future (RFF), June 1971.

13) The George Washington University, "Readings In Technology Assessment," Program Of Policy Studies In Science And Technology, George Washington University, Washington, D.C., August 1975.

14) Gellman Research Associates, "Large Air Cargo Transport Technology Assessment," NASA-Langley Research Center Draft. Final Report, #NSF C1061/NSF-C-ERS76-80328, January 1978.

15) Massachusettes Institute Of Technology, Flight Transportation Laboratory, "An Assessment Of Lighter-Than-Air Technology," FTL R75-1 and FTL R75-2, sponsored by NASA-Navy-DOT-FAA, CR-137799 and CR-137800, dated June, 1975.

16) TRW Systems, "Technology Assessment Of Portable Energy RDT&P," sponsored by NASA, CR-137653, dated April 7, 1975.

17) Peat, Marwick, Mitchell & Co., et al, "Technology Assessment of Future Intercity Passenger Transportation Systems," sponsored by NASA & DOT, CR-137864 through CR-137870, dated March, 1976.

18) University of California at Berkeley, Institute Of Governmental Studies, "Space Disposal of Nuclear Wastes: Socio-Political Aspects," sponsored by NASA, dated December, 1976.

19) H. Harvey Album, "Who Should Conduct Aeronautical R&D For The Federal Government," Pepperdine University, School Of Business And Management, jointly sponsored by NASA, CR-152021, dated August, 1977.

20) "Technology Assessment In Business And Government," Summary and Analysis of Hearings Held by the Technology Assessment Board June 8, 9, 10, and 19, 1976 — Congress Of The United States, Office of Technology Assessment, OTA-X-42, January 1977.

21) "Technology Assessment State-Of-The-Fields," Second Report Of The Technology Assessment Panel Of Engineers Joint Council, September 1976.

22) "Computer-Based Communication in Support of Scientific and Technical Work," Final Report of NASA Contract NAS2-8991, Institute for the Future, NASA CR-137879, March 1976.

23) Sherry R. Arnstein, "Technology Assessment: Opportunities and Obstacles," IEEE Transactions on Systems, Man, and Cybernetics, Vol. SMC-7, No. 8, August 1977.

24) Robert E. Gooch, "Technology Assessment: Scientists Aid Government Decision Making," University of Utah, Mechanical Engineering Department, presented at the AIAA Region VI Student Conference, Stanford University, May 1, 1975.

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16 Abstract

Recent technology assessment studies sponsored by NASA are reviewed, and a summary of the technical results as well as a critique of the methodologies are presented. The reviews include "Assessment of Lighter-Than-Air Technology," "Technology Assessment of Portable Energy RDT&P," "Technology Assessment of Future Intercity Passenger Transportation Systems," and "Technology Assessment of Space Disposal of Radioactive Nuclear Waste." The use of workshops has been introduced as a unique element of some of these assessments. Also included in this report is a brief synopsis of a method of quantifying opinions obtained through such group interactions. Representative of the current technology assessments, these studies cover a broad range of socio-political factors and issues in greater depth than previously considered in NASA-sponsored studies. In addition to the lessons learned through the conduct of these studies, a few suggestions for improving the effectiveness of future technology assessments are provided.

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